Anomalous Emission

Zooming In on Spinning Dust in Perseus

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Caltech
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with the invaluable collaboration of:
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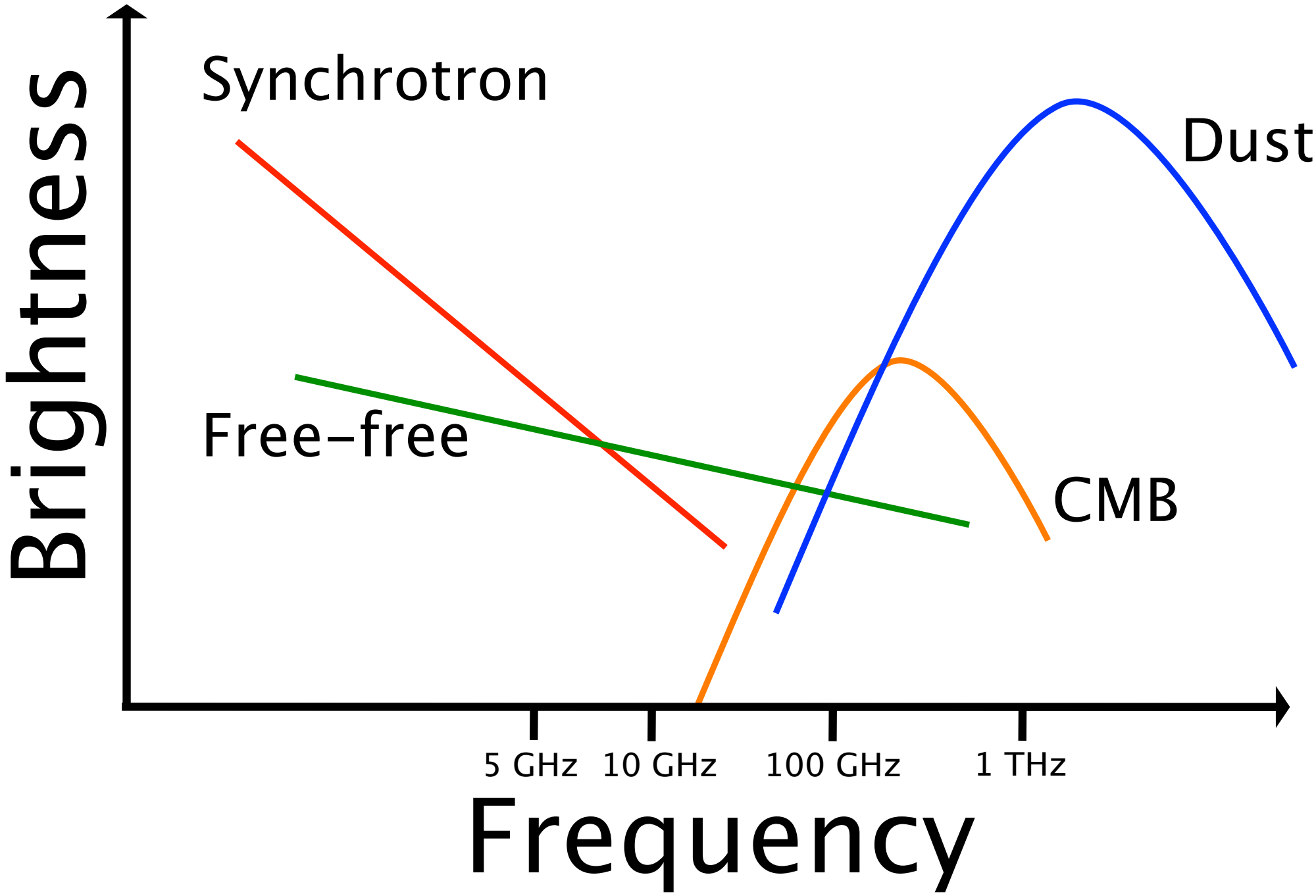
Anthony Readhead, Anna Scaife, Tim Pearson, Laura Perez, Yvette Perrott, Keith Grainge

Overview

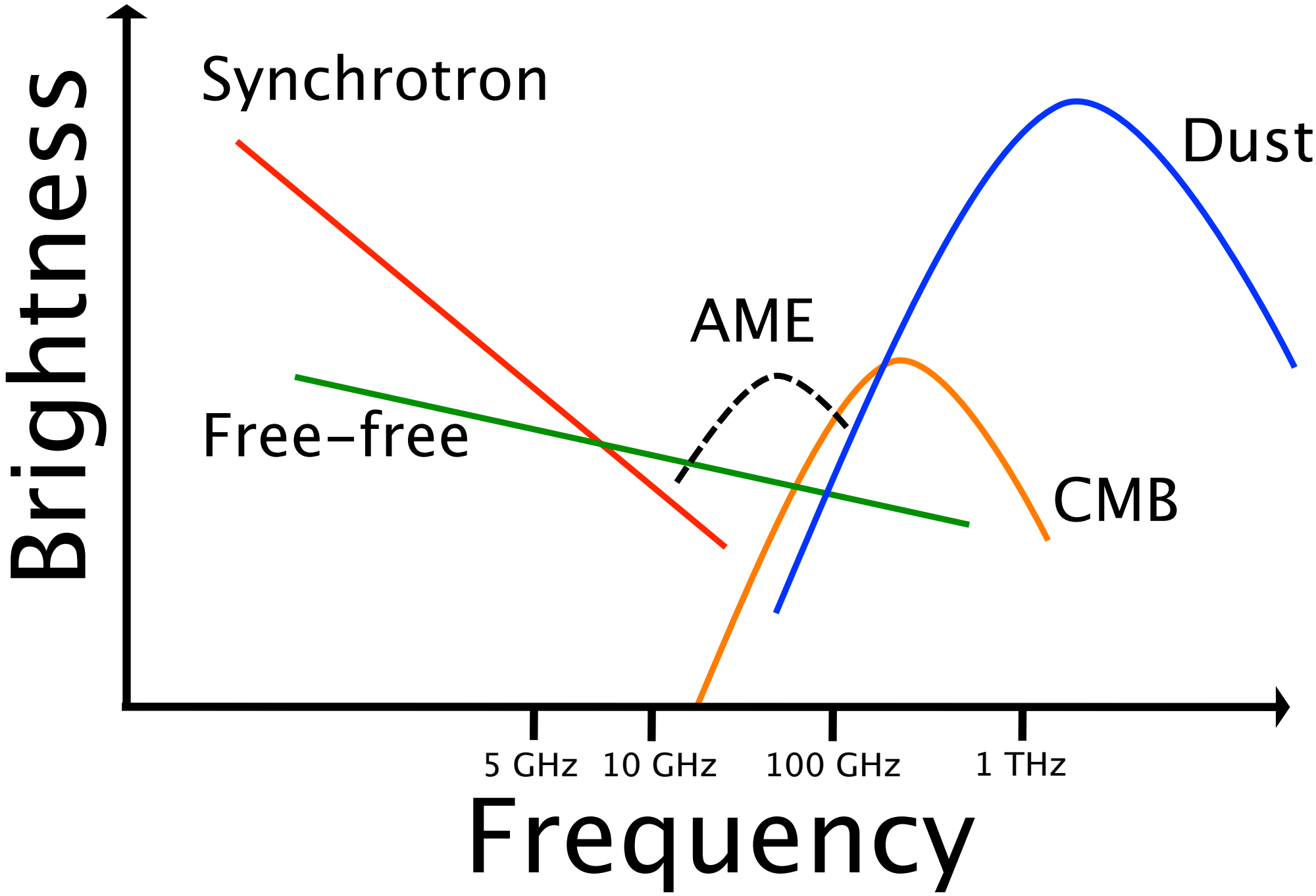
- What is “anomalous emission”?
- Observations of Perseus at 30 GHz
- Comparison to thermal dust emission
- Measuring spectral index

What is anomalous emission?

- Anomalous microwave emission (AME):
  excess of emission at 10s of GHz
  unaccounted for by known emission mechanisms
- Discovery:
  - Power excess in CMB experiments: COBE 1996, Saskatoon 1997
  - 15 GHz spatial correlation with infrared: RING5M 1996



Slide Credit: Matthew Stevenson



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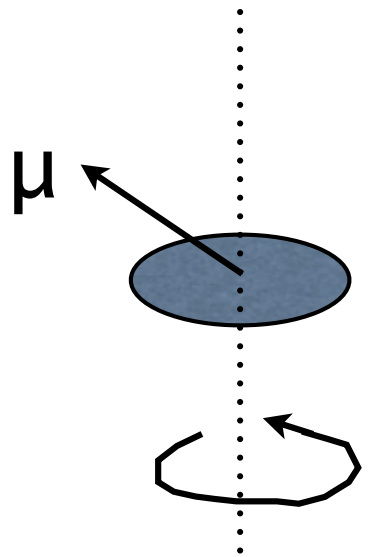
Theory

Electric dipole emission from small, rotating grains

(Draine & Lazarian 1998)



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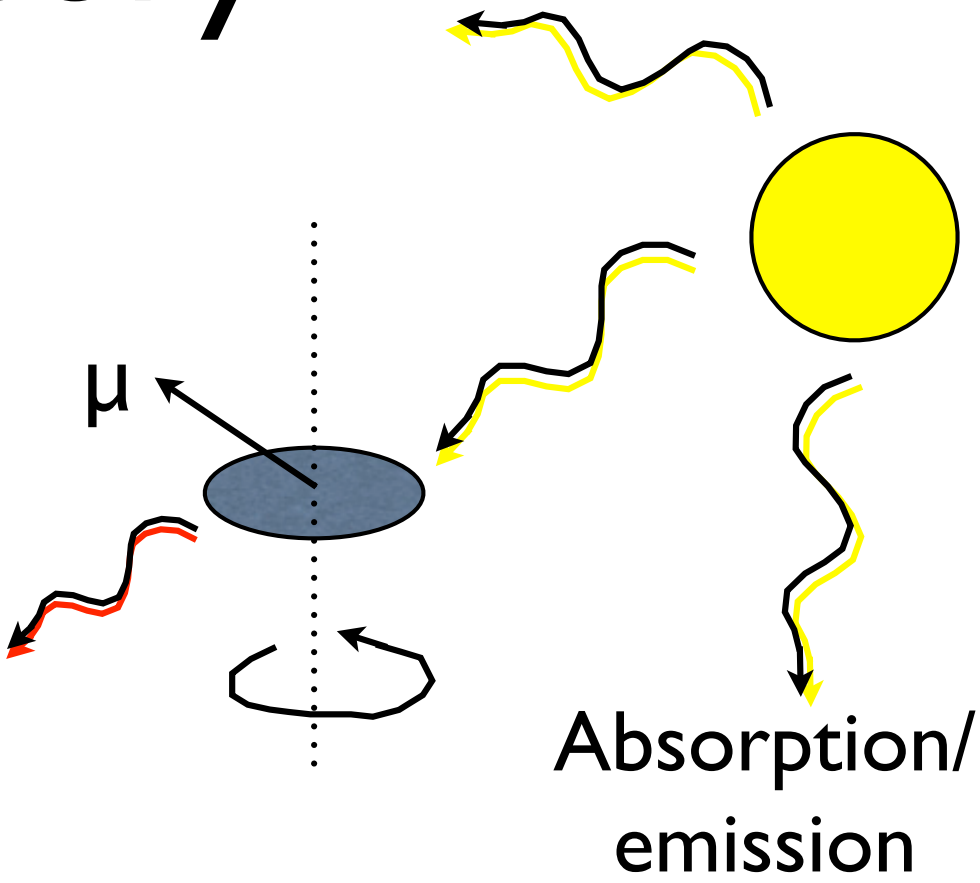

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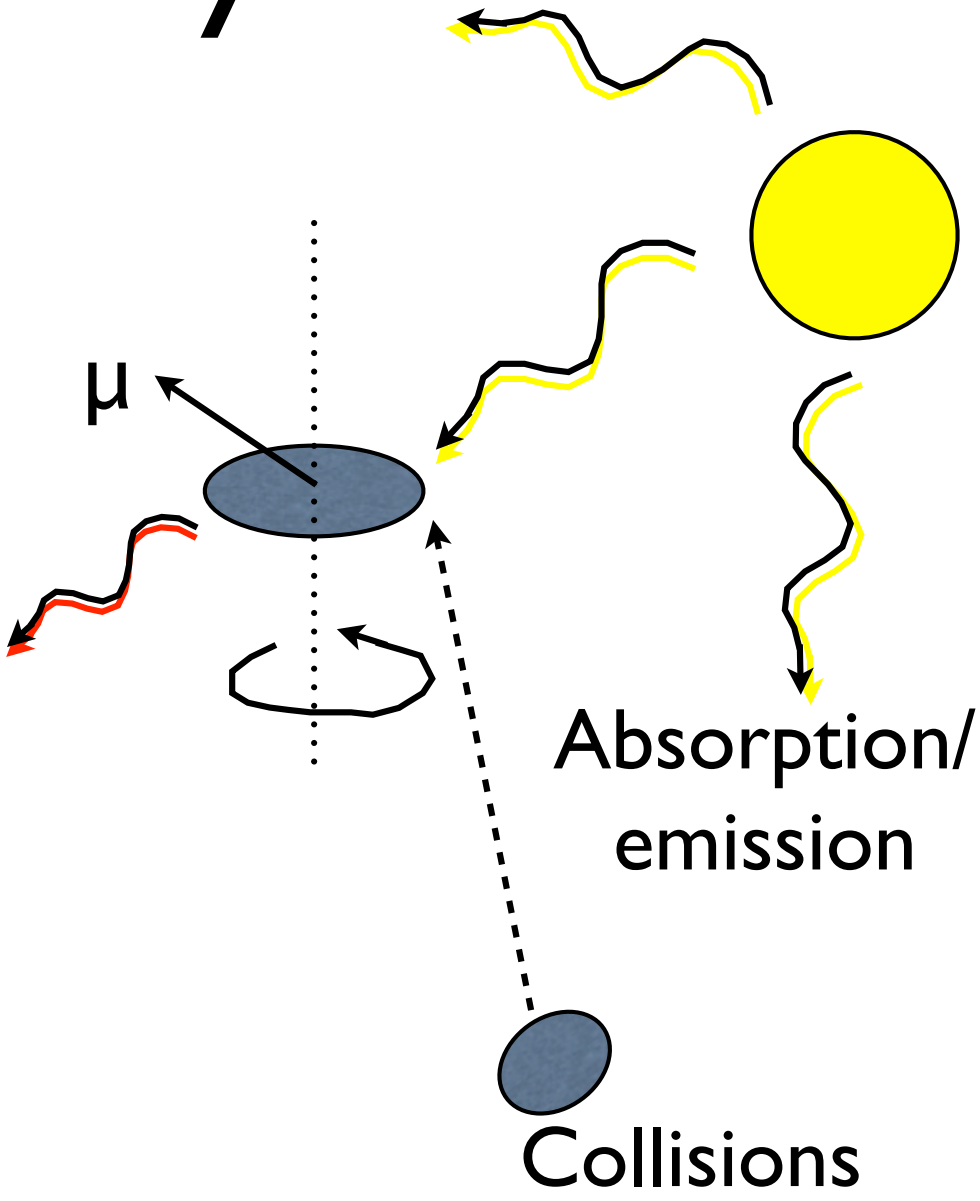
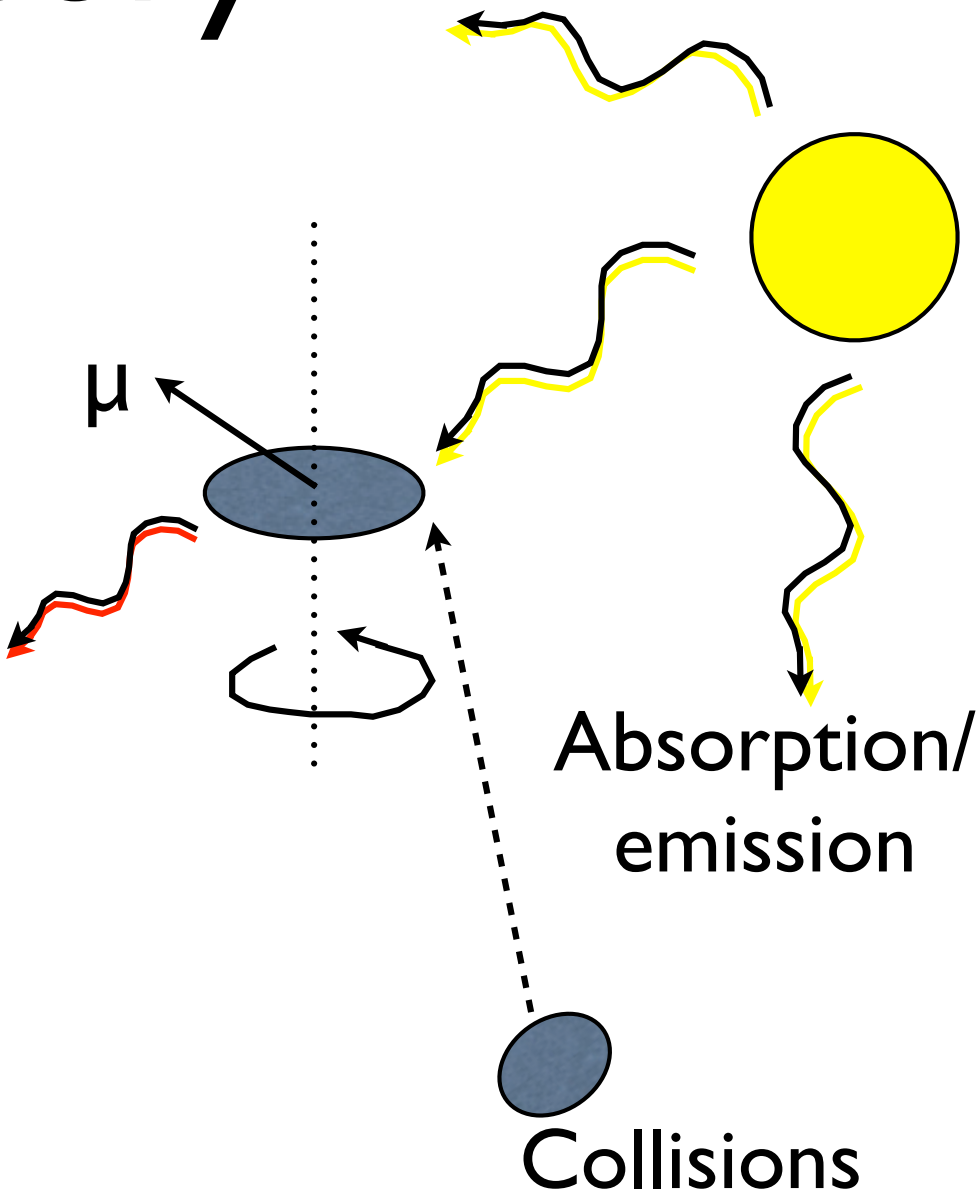


Theory

Electric dipole emission from small, rotating grains

(Draine & Lazarian 1998)

- $kT_{rot} \sim I\omega^2$
- $I \sim \rho r^5$
- Solve for r:
- r ~ 1 nm



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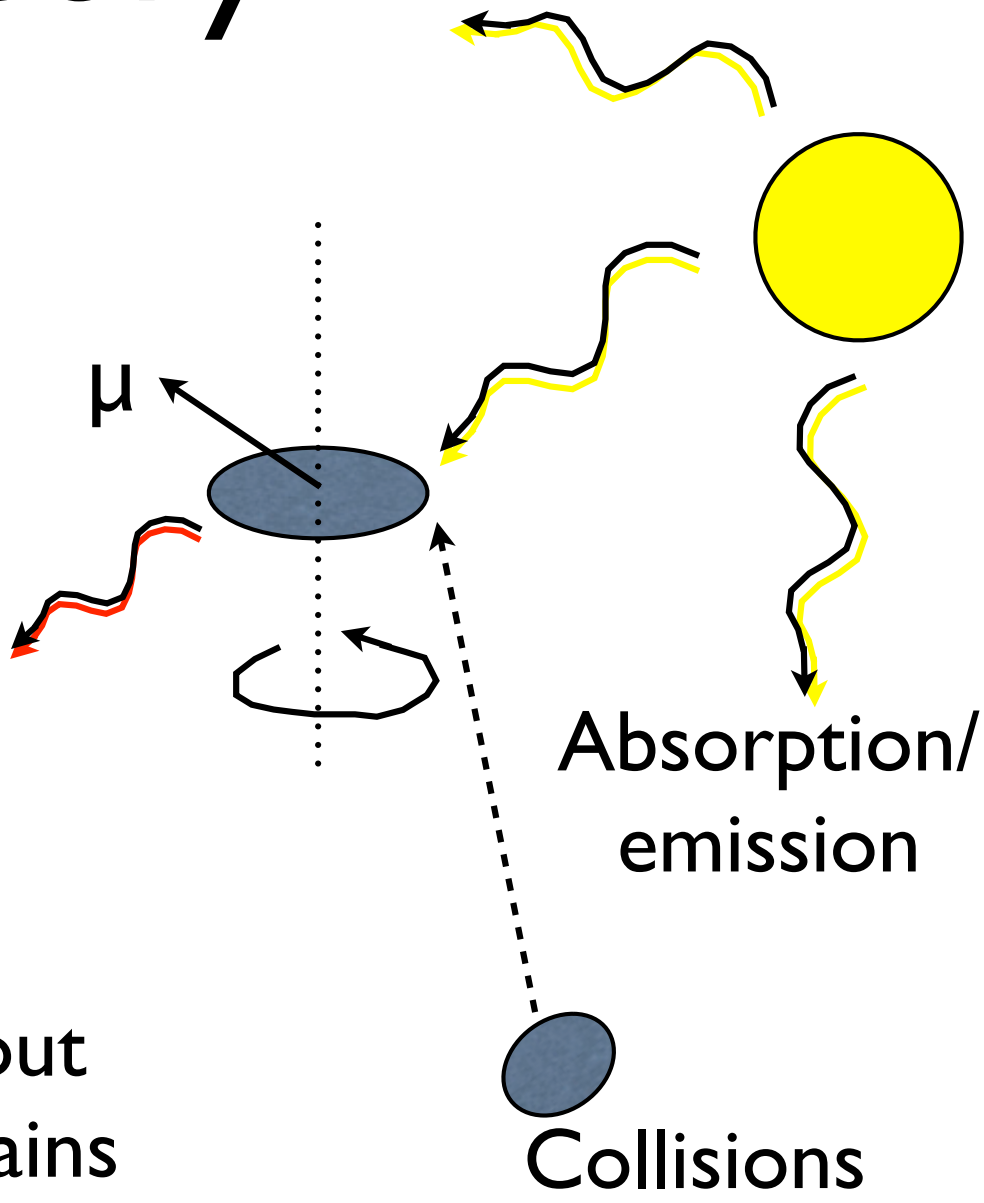
AME spectrum tells us about size distribution of small grains



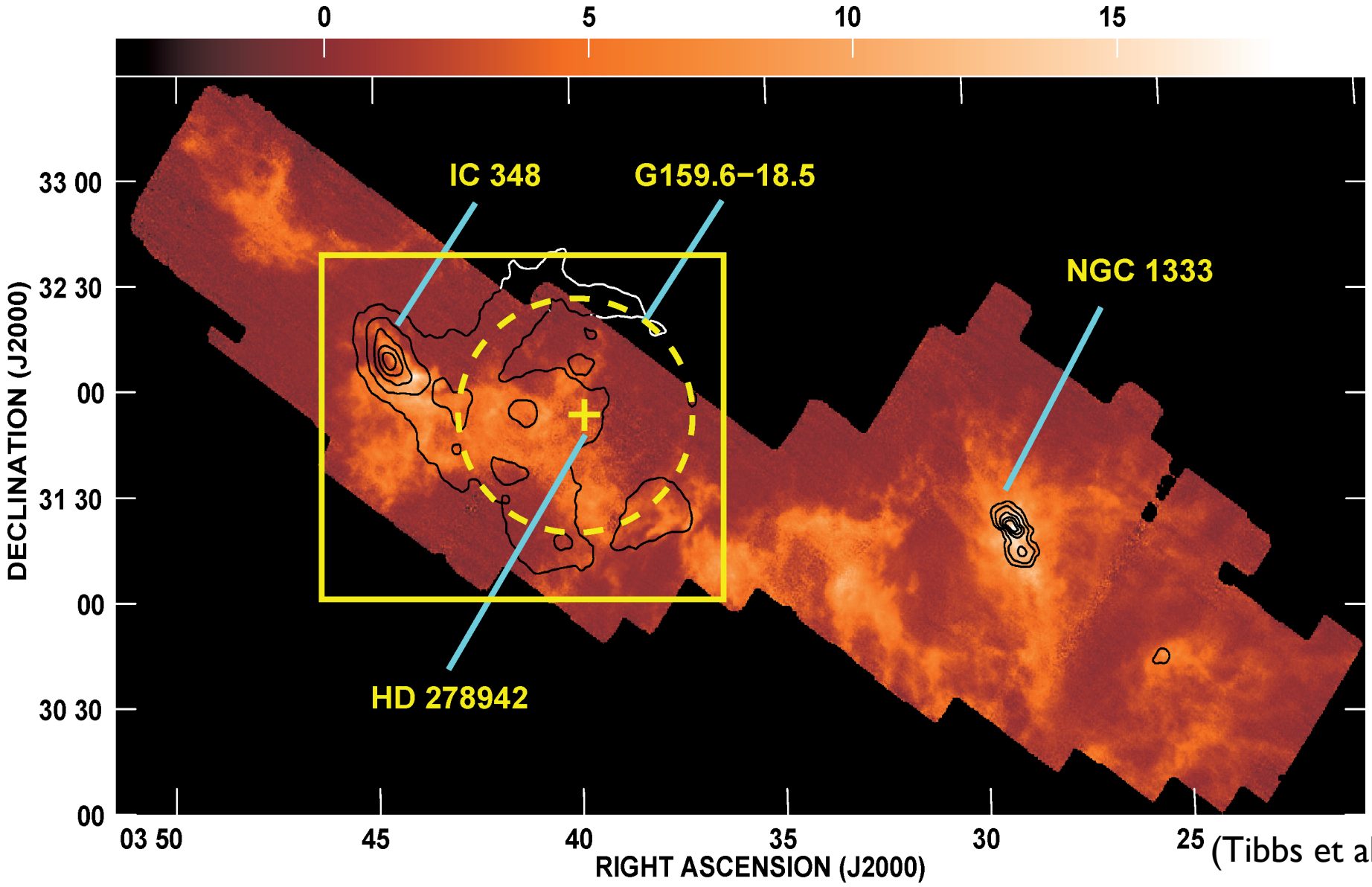
Why study AME

- Intrinsic interest - poorly understood emission mechanism
- Foreground to CMB with poorly constrained polarization
- Potential insight into dust properties

Unanswered Questions

- Is spinning dust the only emission mechanism?
- Can we predict AME levels using other environmental properties?
- What is the spatial power spectrum?
- Can we constrain physical properties of dust from AME measurements?

Perseus molecular cloud

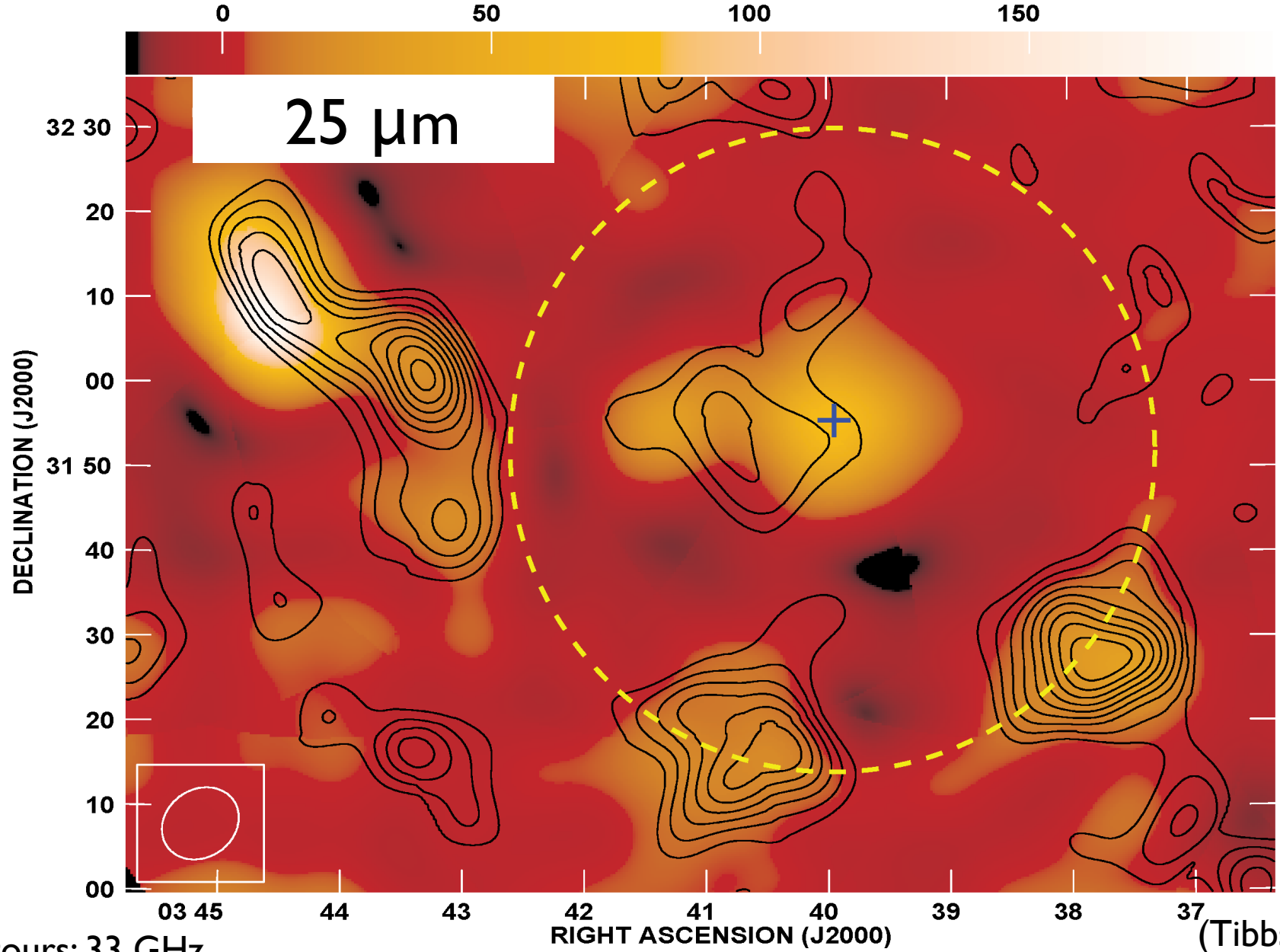


(Tibbs et al 2010)

Contours: IRIS 100 μm Image: ^{13}CO

What's so anomalous?

Correlation with infrared (better than free-free)



Contours: 33 GHz

(Tibbs et al 2010)

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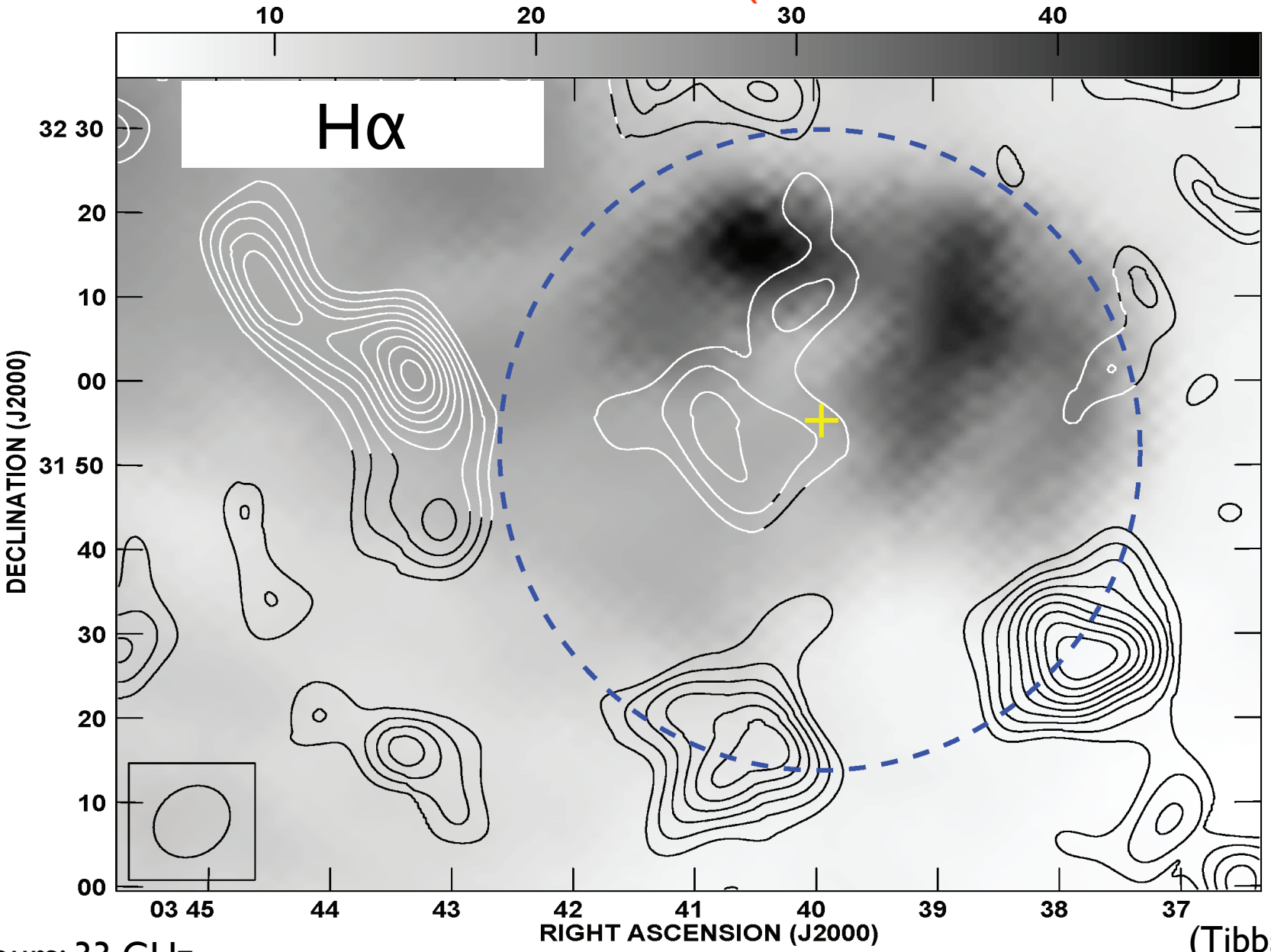
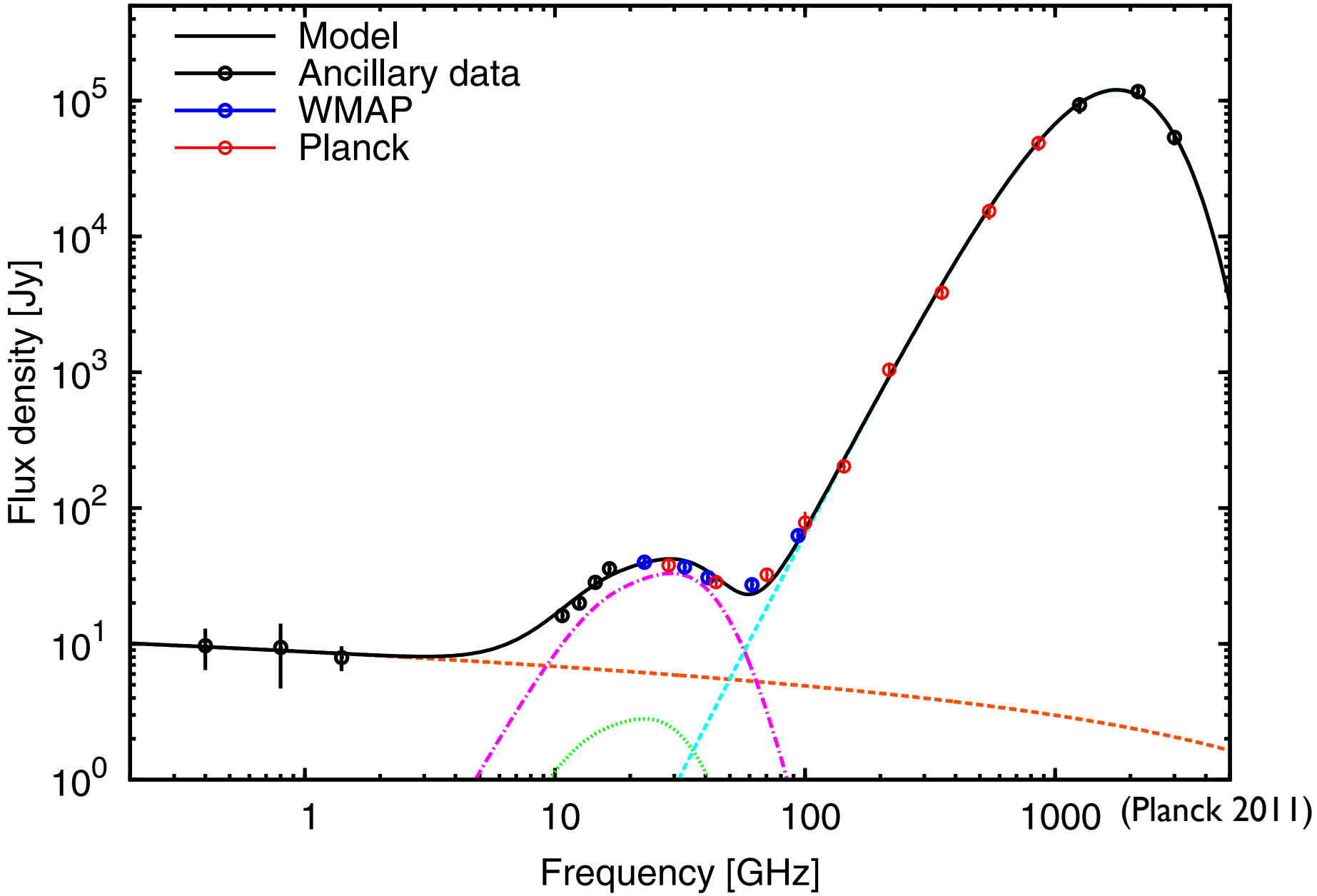


Contours: 33 GHz

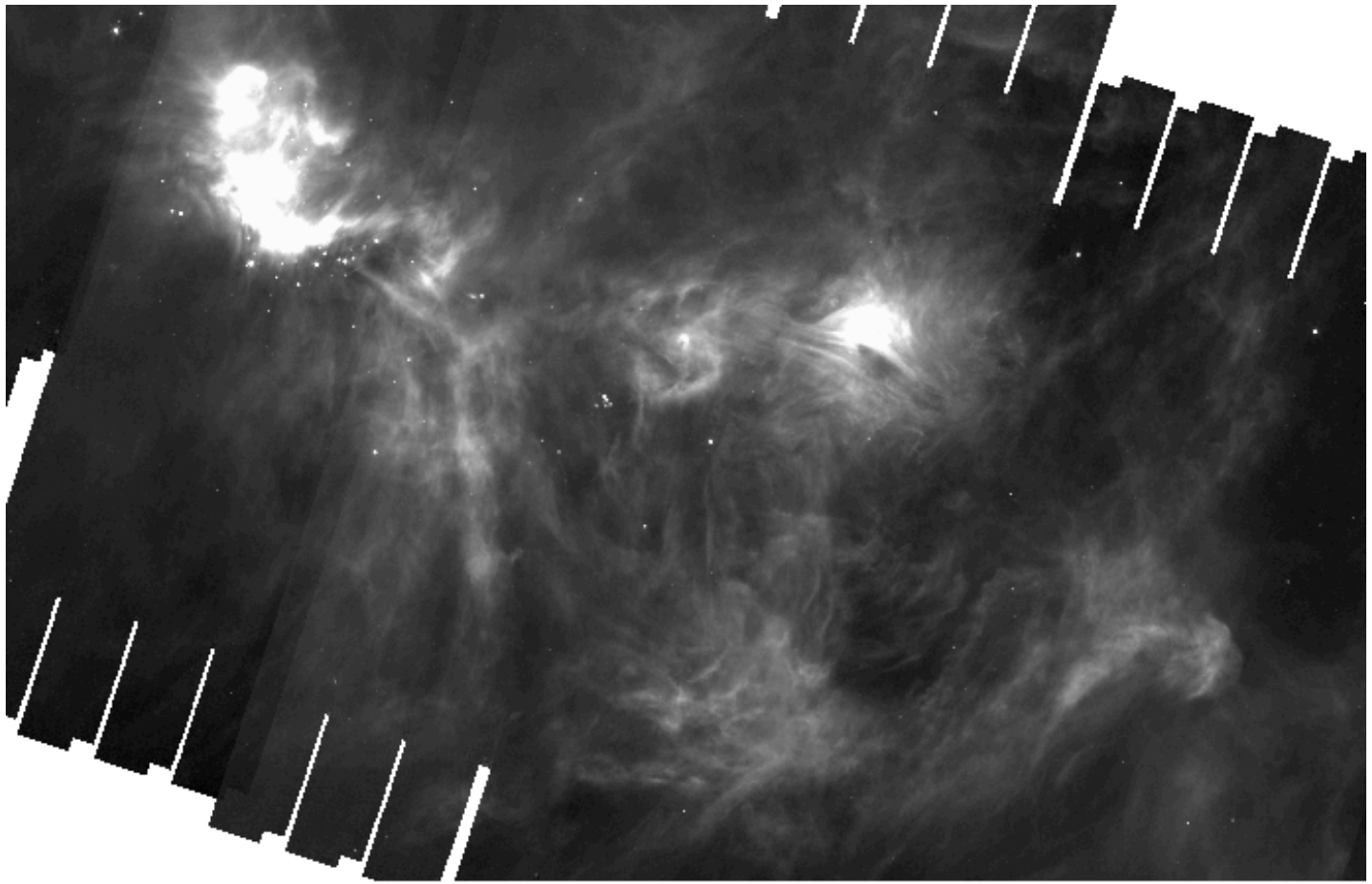
(Tibbs et al 2010)

What's so anomalous?

Excess in spectrum



Spitzer: Perseus

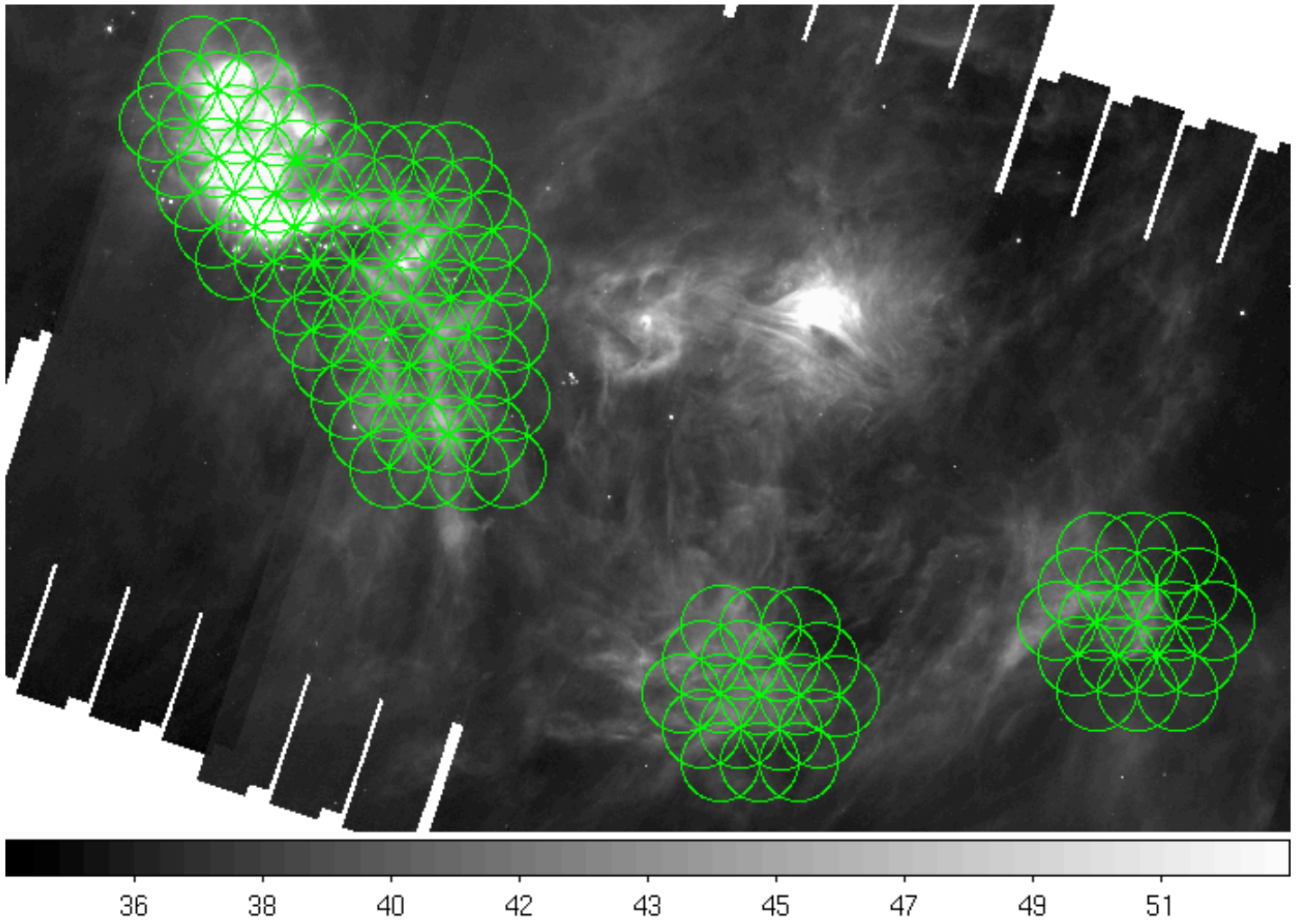


24 micron

Combined Array for Millimeter-wave Astronomy (CARMA) 8-Element Array

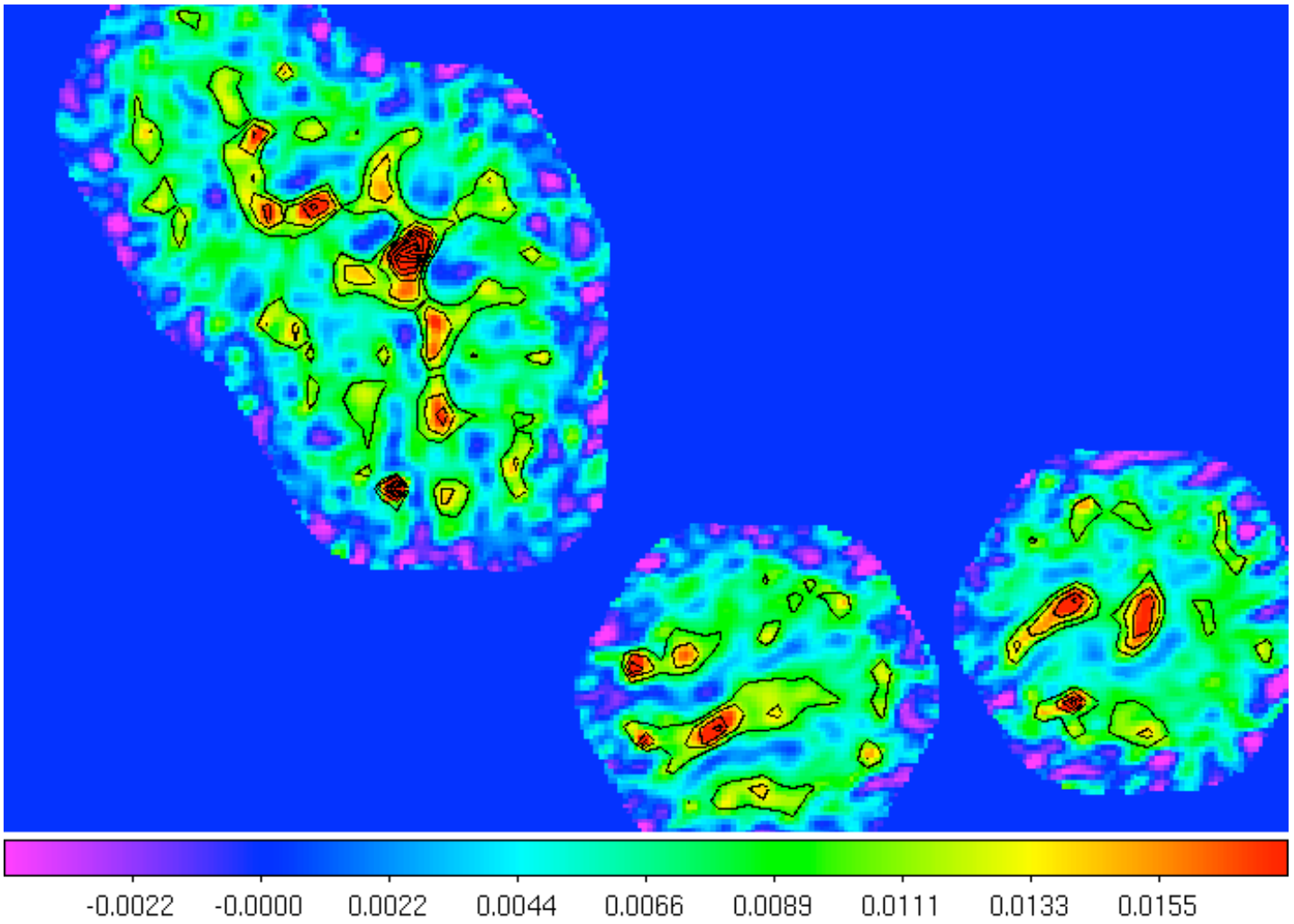
Frequency	31 GHz
Bandwidth	8 GHz (16 x 500 MHz)
Antennas	6 x 3.5-m
Shortest baseline	4 m / 0.4 kλ / 9’
Longest baseline	12 m / 1.2 kλ / 3’
Latitude	37°

CARMA: Perseus



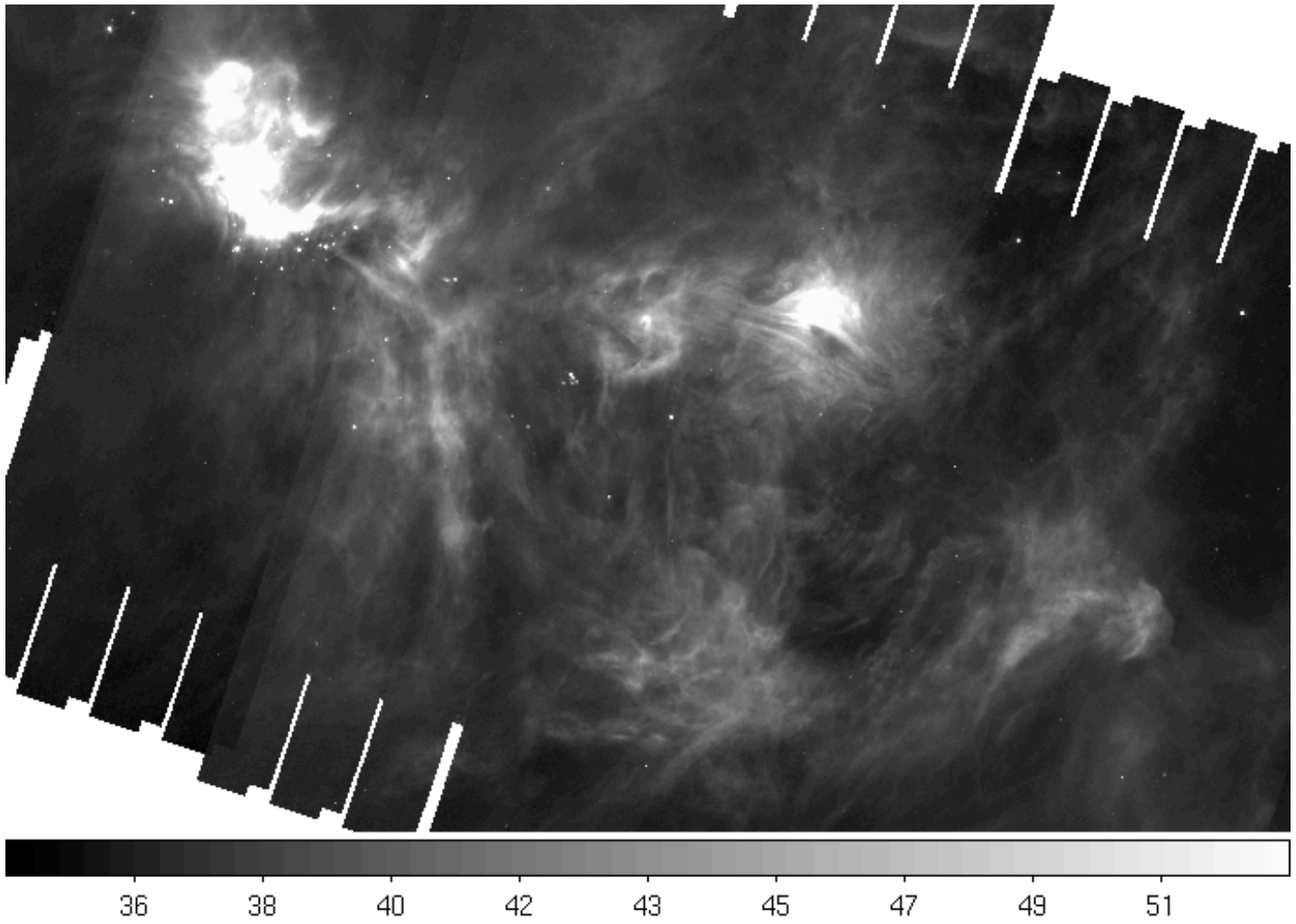
Primary beam: 8’

CARMA: Perseus



31 GHz - Resolution: 2.5’

Spitzer: Perseus



24 micron

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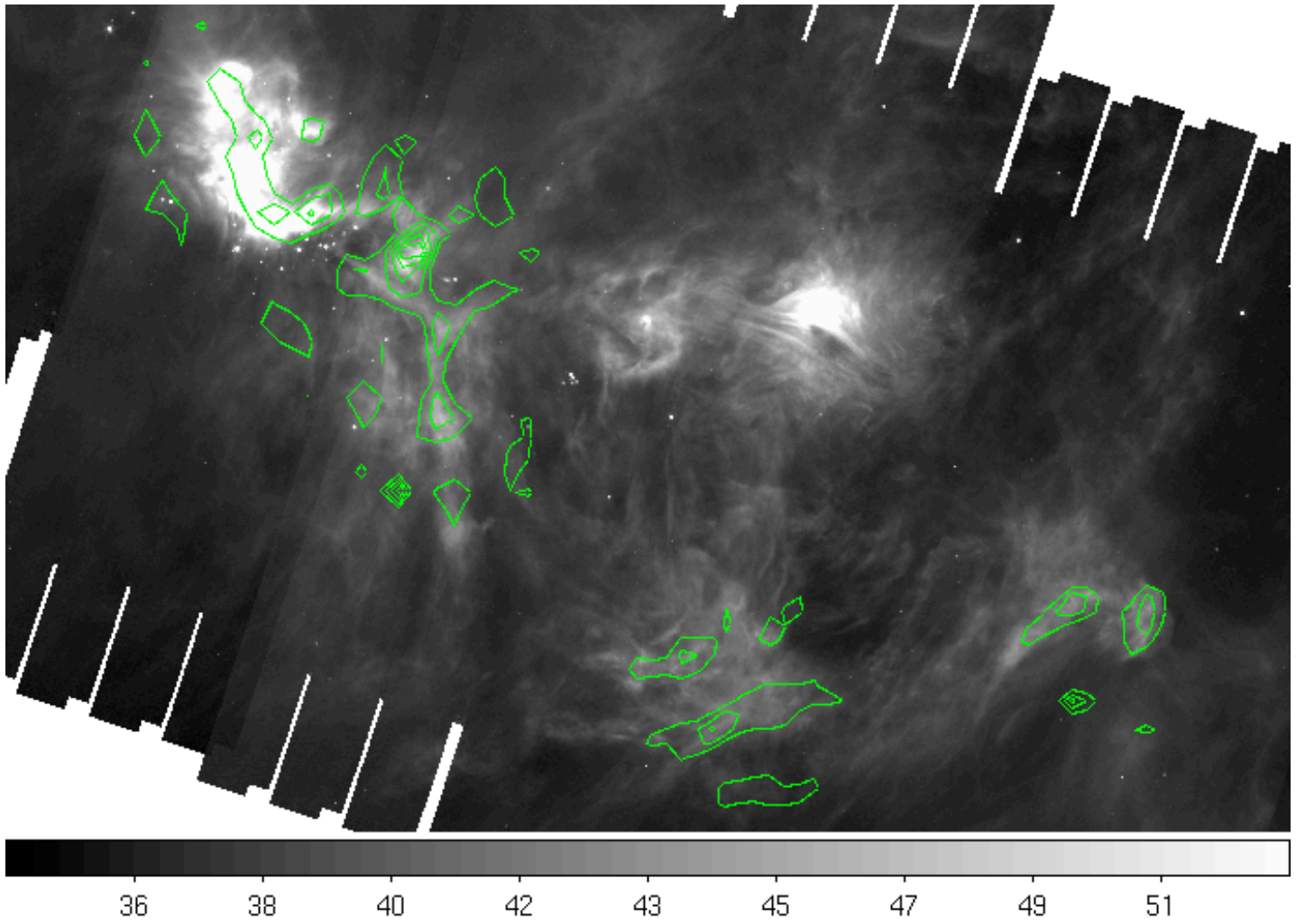
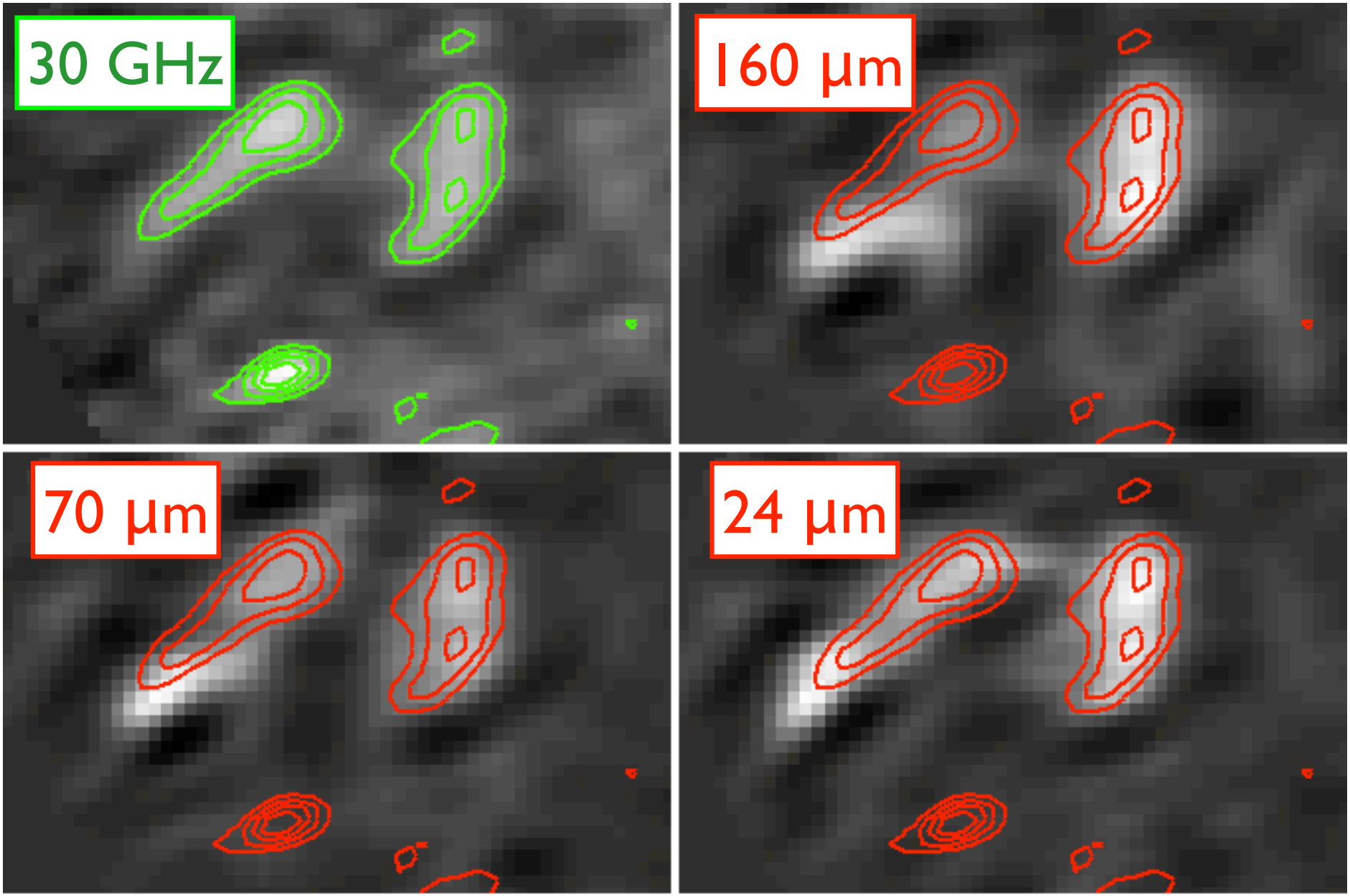


Comparison with IR

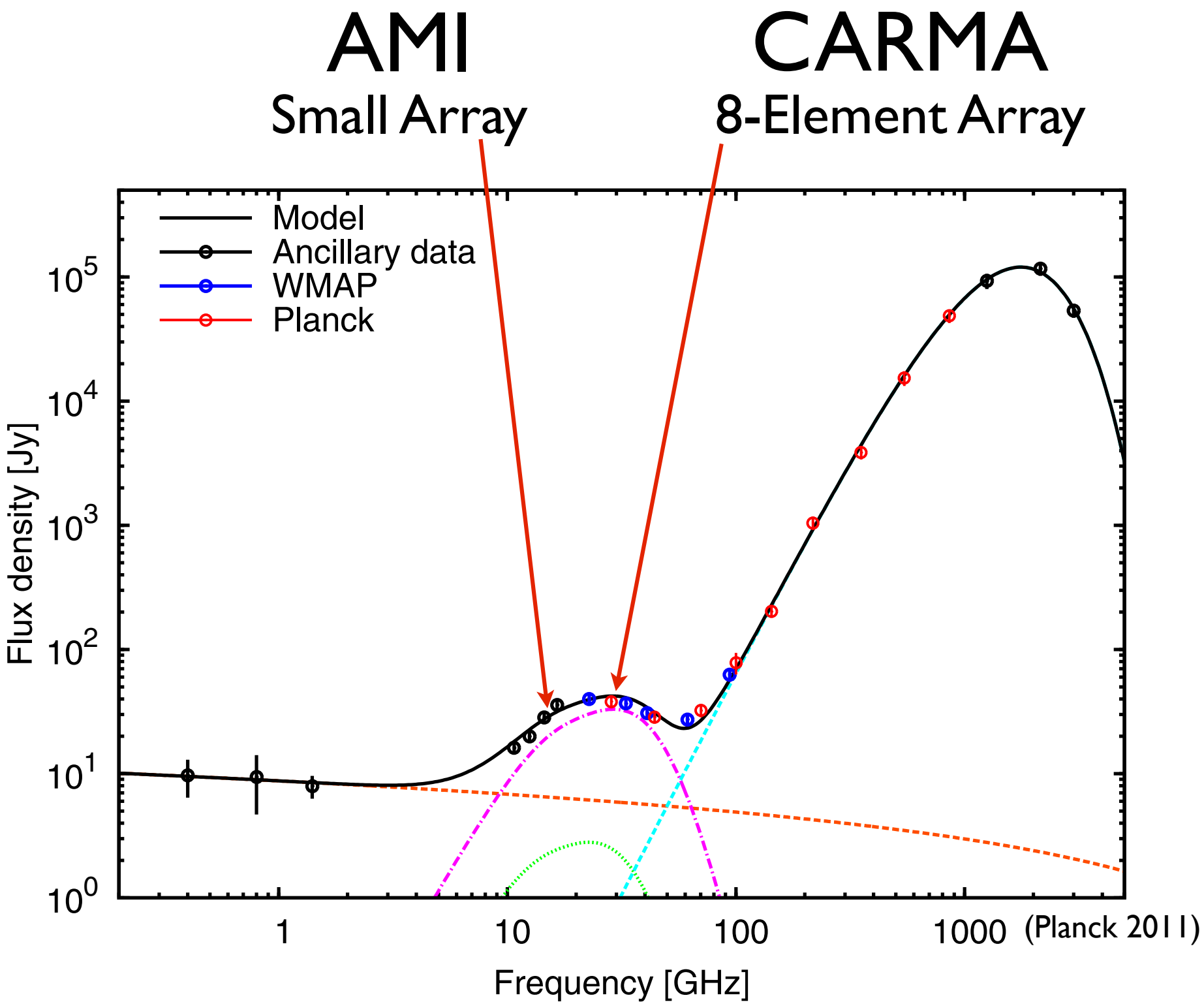


Arcminute Microkelvin Imager (AMI)

AMI observations: Tibbs et al, in prep

Combined Array for Millimeter-wave Astronomy (CARMA)

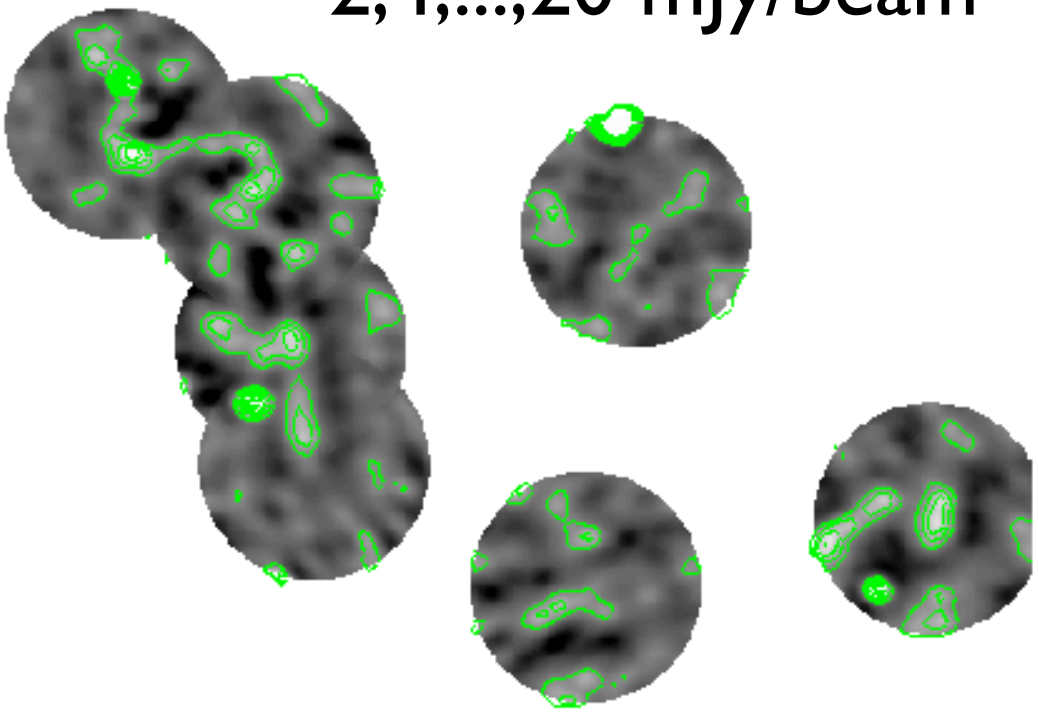
	AMI Small Array	CARMA 8-Element Array
Frequency	15 GHz	31 GHz
Bandwidth	6 GHz (8 x 750 MHz)	8 GHz (16 x 500 MHz)
Antennas	10 x 3.7-m	6 x 3.5-m
Shortest baseline	5 m / .25 kλ / 14’	4 m / 0.4 kλ / 9’
Longest baseline	20 m / 1 kλ / 3.5’	12 m / 1.2 kλ / 3’
Latitude	52°	37°


AMI
Small Array
CARMA
8-Element Array
Model
Ancillary data
WMAP
Planck
Flux density [Jy]
10^0
10^1
10^2
10^3
10^4
10^5
1
10
100
1000
Frequency [GHz]
(Planck 2011)

Perseus:
15 and 30 GHz

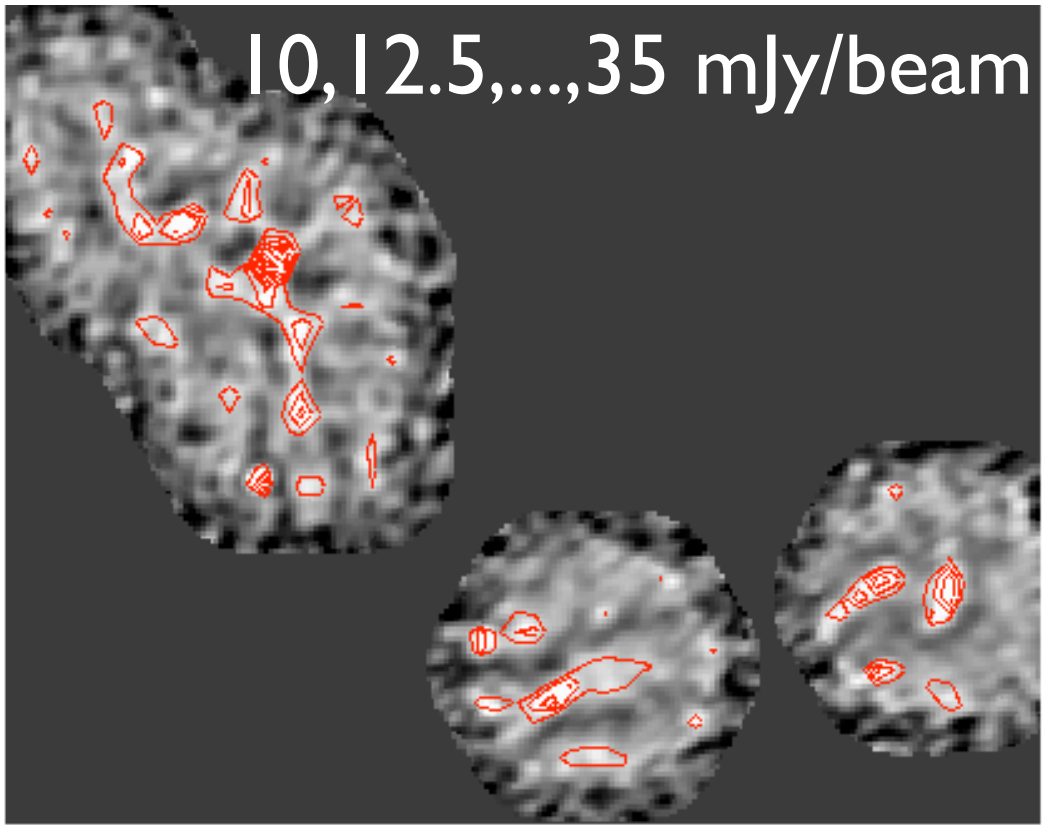
AMI

2,4,...,20 mJy/beam

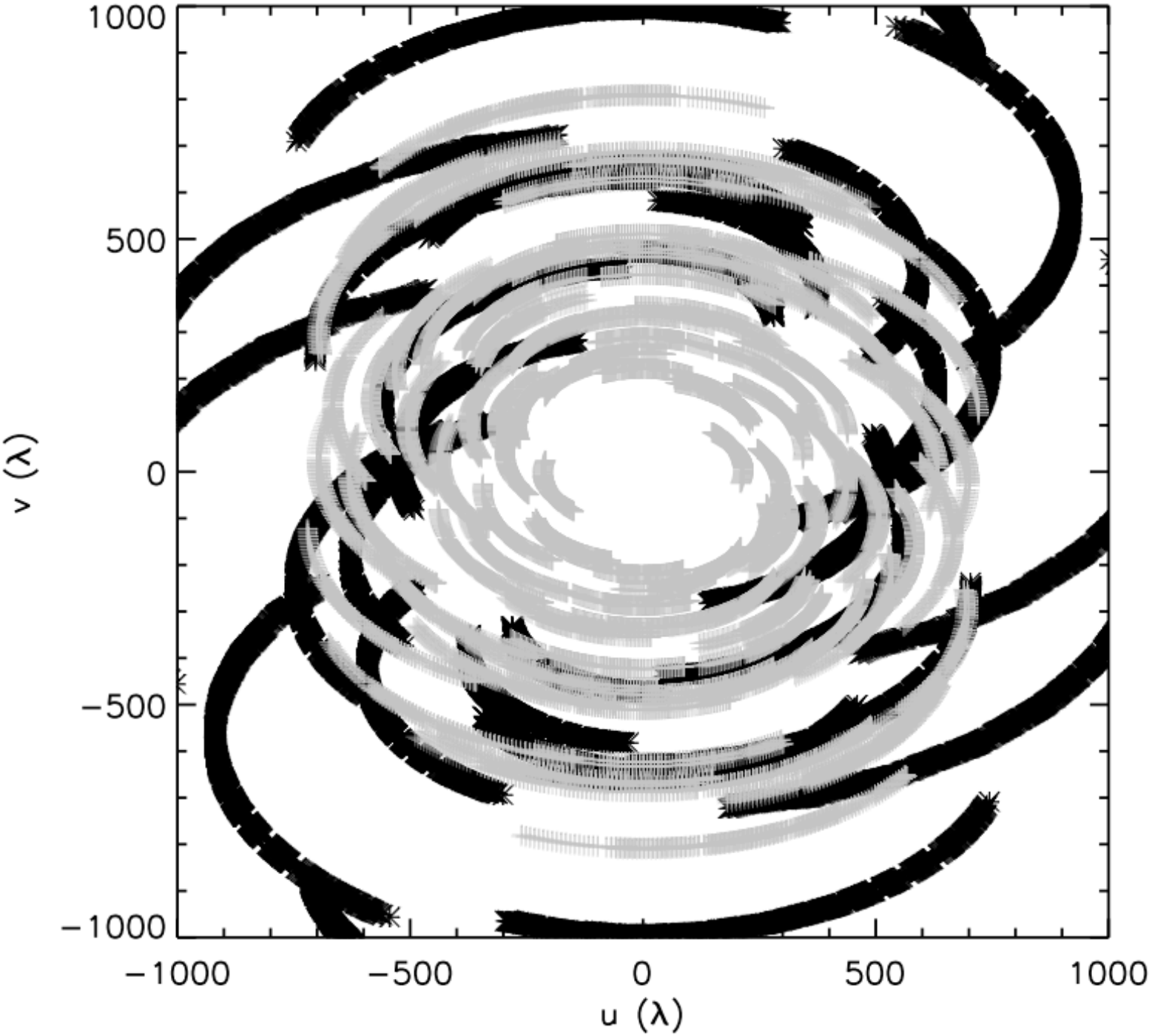


CARMA

10,12.5,...,35 mJy/beam



uv Coverage

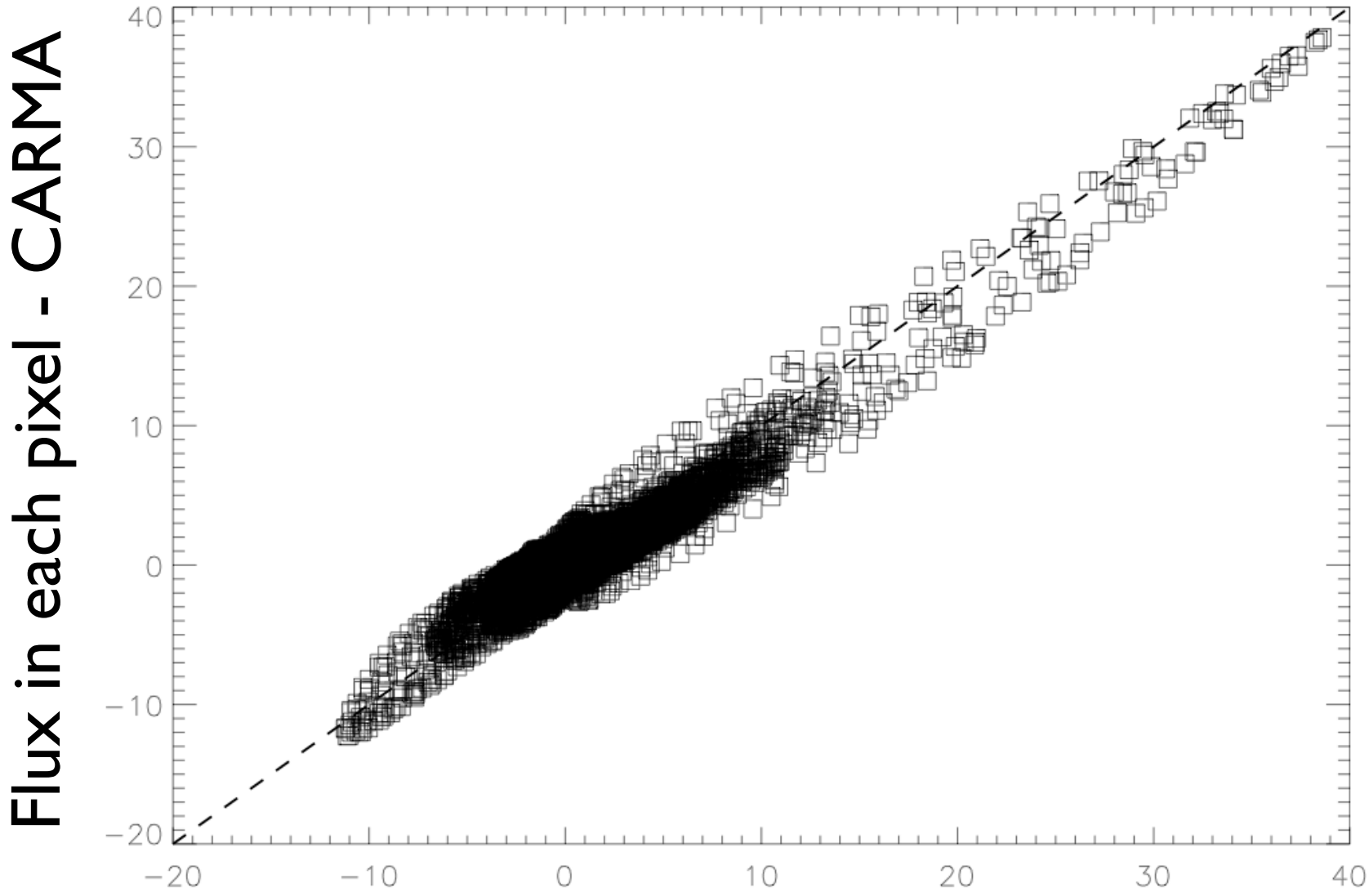


AMI

CARMA

Simulations

assumed same flux for AMI & CARMA

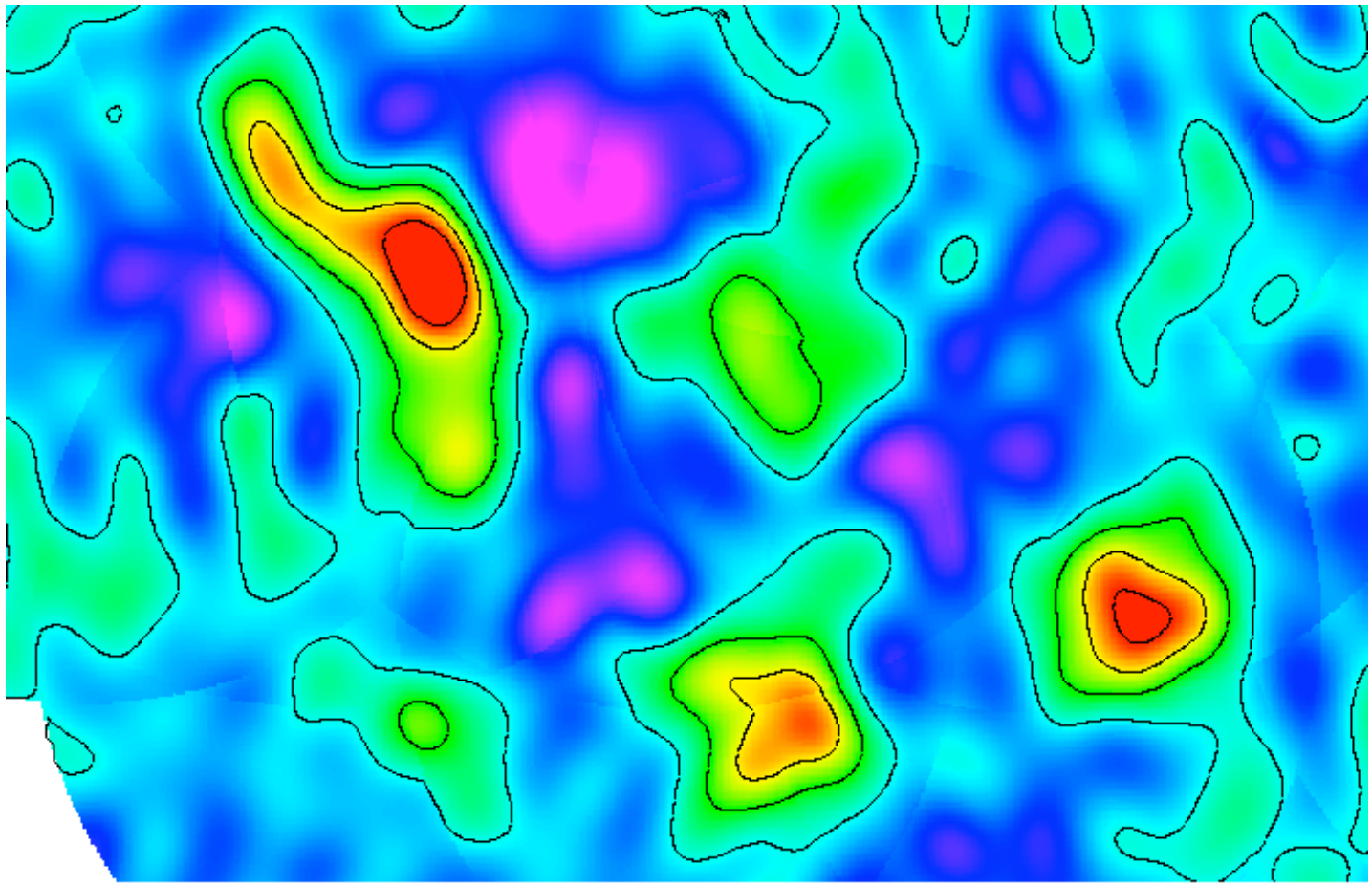


Future Work

- Spatially resolve spectral index variations
- Constrain free-free & thermal dust - ATA, Herschel
- Combine data from multiple interferometers to probe larger range of spatial scales
- CARMA upgrade - 1 cm receivers on large dishes, long baselines - 0.5’ resolution - pair with AMI Large Array

Supplementary Slides

VSA: Perseus



33 GHz - Resolution: 7’

What's so anomalous?
(about the microwave emission)

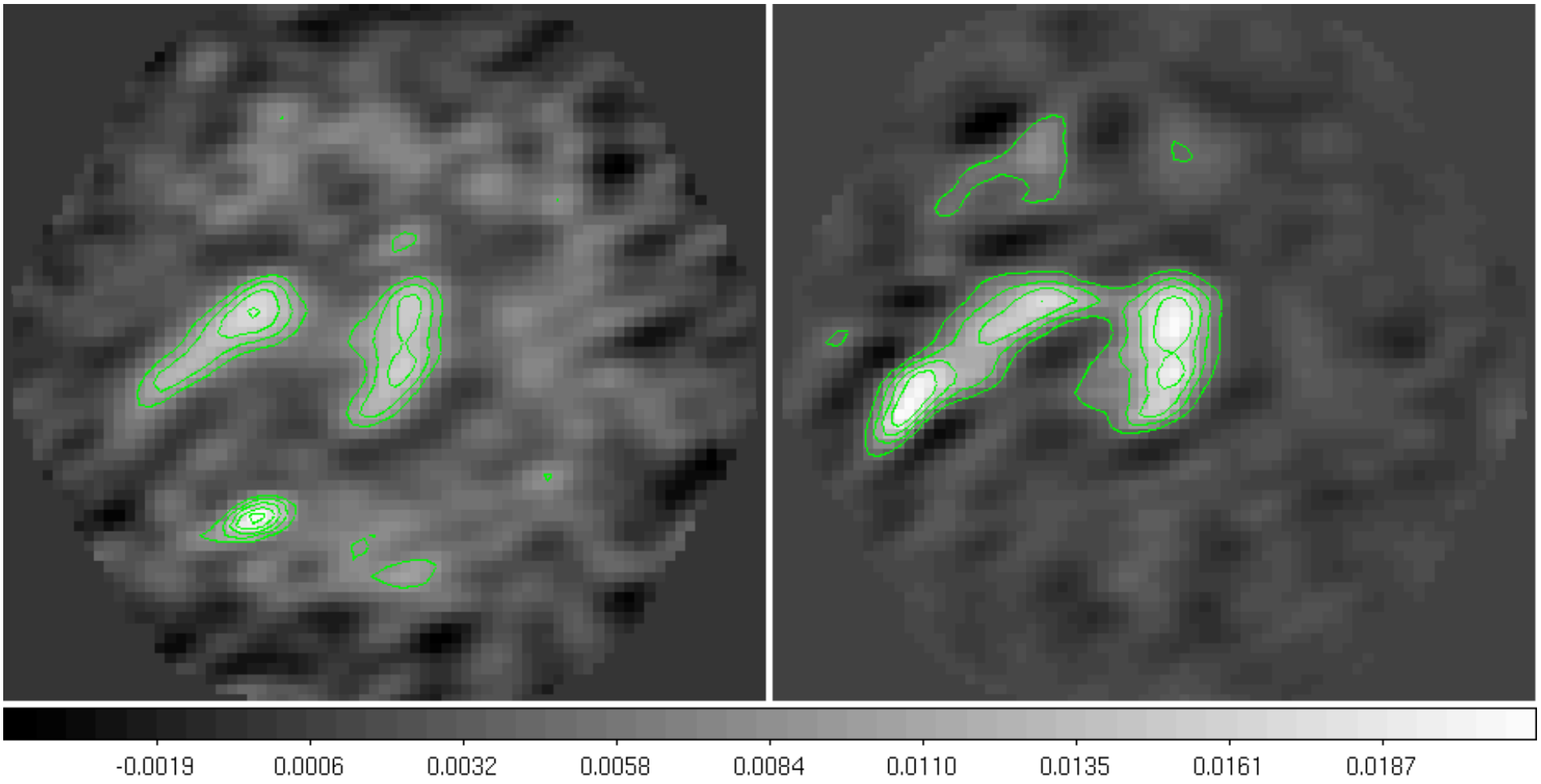
- Correlation with infrared (better than free-free)

- Excess in spectrum

Comparison with IR

30 GHz

Filtered 24 μm



How to Compare

- Compare in image plane:
  - As is
  - After filtering uv coverage to match
- Compare in uv plane:
  - Simultaneous component fitting
  - Compare each to simulated visibilities

Free-free & Thermal Dust

- Free-free: planned ATA observations
- Thermal dust: Herschel 500 micron

Simulated Visibilities

- uvdist vs. amp for simulated & real data from each interferometer - use 24 microns
- use this to derive overall spectral index